California's
Advanced Clean Cars
Midterm Review

Appendix L:
Emissions Impact Assessment for the 1 mg/mi standard

January 18, 2017

California Environmental Protection Agency
Air Resources Board

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I.A PM Health Effects

California experiences some of the highest concentrations of PM2.5 in the nation.[1] The majority of California's population lives in areas that exceed the National Ambient Air Quality Standard for PM2.5.[2] This standard is set by the U.S. EPA, and is designed to protect human health and the environment from exposure to harmful levels of PM2.5. As part of the standard setting process, U. S. EPA assesses scientific studies that link exposure to PM2.5 to health effects, including hospitalization due to respiratory illness, and premature death from cardiopulmonary disease.[3] The U.S. EPA has determined that both long-term and short-term exposure to PM2.5 plays a "causal" role in premature death, meaning that a substantial body of scientific evidence shows a relationship between PM2.5 exposure and increased mortality, a relationship that persists when other risk factors such as smoking rates and socioeconomic factors are taken into account[3]. These effects are also evidenced by a number of studies that have linked daily exposure to PM2.5 with hospitalization for heart and lung related causes, as well as an increase in emergency room visits, exacerbation of asthma, and other respiratory diseases[3]. Black carbon is a significant component of particle matter pollution, which has been linked to adverse health impacts and climate change.

In addition, research studies have found that traffic pollution specifically may be associated with a number of health impacts including slower lung development,[4] increased symptoms and medication use in asthmatic children,[5,6] and even increases in the development of asthma in children.[7] A recent analysis in the Children's Health Study[8] demonstrated that both regional particulate matter pollution and local near roadway exposures impact children's health independently, resulting in reduced lung function.

In "The State of the Air 2016",[9] the American Lung Association found that even with continued improvement in air quality, many people live where the air is unhealthy for them to breathe.

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[1] EPA, 2016. U.S. Environmental Protection Agency. "Air Quality Statistics Report". September 2016. https://www.epa.gov/outdoor-air-quality-data/air-quality-statistics-report

[2] ARB, 2015. Air Resources Board. "Federal Standard Area Designations". September 7, 2016. https://www.arb.ca.gov/desig/feddesig.htm

[3] EPA, 2009. U.S. Environmental Protection Agency. "Final Report: Integrated Science Assessment for Particulate Matter". October 2009. https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=216546

[4] Gauderman, 2007. Gauderman WJ1, et. al. "Effect of exposure to traffic on lung development from 10 to 18 years of age: a cohort study". Lancet. 2007 Feb 17; 369(9561): 571-7.

[5] Gauderman, 2005. Gauderman WJ1, et. al. "Childhood asthma and exposure to traffic and nitrogen dioxide. Epidemiology". 2005 Nov;16(6):737-43.

[6] McConnell, 2006. Rob McConnell, et. al. Traffic, Susceptibility, and Childhood Asthma. Environ Health Perspect. 2006 May; 114(5): 766–772.

[7] McConnell, 2010. Rob McConnell, et. al. "Childhood Incident Asthma and Traffic-Related Air Pollution at Home and School". Environ Health Perspect. 2010 Jul; 118(7): 1021–1026.

[8] Urman, 2014. Robert Urman, et. al. "Associations of Children's Lung Function with Ambient Air Pollution: Joint Effects of Regional and Near-roadway Pollutants". Thorax. 2014 Jun; 69(6): 540–547.

[9] ALA, 2016, American Lung Association. "State of the Air", 2016

Based on year-round and short-term PM exposure, Los Angeles reported its best air quality ever. However, Bakersfield returned to the top of the most-polluted list for year-round and short-term PM exposures. California cities hold the top 5, and top 4, positions on the lists of worst cities for year-round and short-term PM exposures, respectively. Studies show that cleaning up particle pollution has immediate health benefits and the United States could prevent approximately 34,000 premature deaths a year by lowering annual levels of particle pollution by 1 µg/m. Reductions in air pollution can be expected to produce rapid improvements in public health and fewer deaths within the first two years of reduced exposure.

I.B Black Carbon

Black carbon (BC) is a strong light-absorbing component of fine particulate matter (PM) produced during incomplete combustion of fuels.[10] Black carbon contributes to climate change, both directly by absorbing sunlight and giving off heat, and indirectly by depositing on snow and accelerating snow melt or by interacting with clouds and affecting cloud formation. Both on global and regional scales, black carbon also causes climate change through its contribution to warming and its suppression of precipitation. California may be especially vulnerable to the climate effects of BC. Global warming affects summer water supplies in California that rely predominantly on runoff from mountain snowpack located within the State as well as in the Rocky Mountains (via the Colorado River). Furthermore, a warmer atmosphere over already dry regions, combined with less mountain runoff during the summer months, enhances conditions conducive for wildfires. An increase in the number and intensity of wildfires would add to the number of black carbon particles, further increasing the attendant climate impacts.

Unlike longer-lived greenhouse gases, BC has a very short atmospheric lifetime, only a week or two. Consequently, it has a strong correlation with regional emission sources and, correspondingly, its emission reductions have immediate climate and public health benefits.[11,12] A comprehensive review article[13] suggests that BC is the second most important human-caused emission in terms of its climate forcing in the present-day atmosphere; only carbon dioxide (CO_2) is estimated to have a greater climate forcing impact. Furthermore, theoretical modeling and laboratory experiments demonstrate that coatings on BC can enhance BC's light absorption. The mechanism for this enhancement is one in which the coating acts as a lens to focus radiation into the absorbing BC core.[14] Increases in BC coating result from a combination of changing sources and photochemical aging processes. Therefore, reducing BC emissions provides near-term climate benefits, complementing efforts to reduce CO_2 emissions.

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http://www.lung.org/assets/documents/healthy-air/state-of-the-air/sota-2016-full.pdf

[10] EPA, 2011. U.S. Environmental Protection Agency. "Report to Congress on Black Carbon" April 11, 2012. https://cfpub.epa.gov/si/si_public_record_report.cfm?direntryid=240148

[11] UNEP, 2011. United Nations Environment Programme (UNEP) and World Meteorological Organization (WMO). "Integrated Assessment of Black Carbon and Tropospheric Ozone". http://www.unep.org/dewa/Portals/67/pdf/BlackCarbon_report.pdf

[12] Shindell, 2012. Shindell, D., et. al. "Simultaneously Mitigating Near-Term Climate Change and Improving Human Health and Food Security." *Science* 335 (6065): 183–189. January 13, 2012. doi: 10.1126/science.1210026.

[13] Bond, 2013. T. C. Bond., et. al. Bounding the role of black carbon in the climate system: A scientific assessment. *Journal of Geophysical Research: Atmospheres*. June 6, 2013. doi:10.1002/jgrd.50171

[14] Cappa, 2012. Cappa C. D. et al. "Radiative absorption enhancements due to the mixing state of atmospheric black carbon". Science 337, 1078–1081 August 2012. http://science.sciencemag.org/content/337/6098/1078

Airborne PM represents a complex mixture of organic and inorganic substances that originate from a number of natural and man-made sources. Black carbon is a component of PM, and the scientific literature has shown a consistent association between PM2.5 exposure and hospitalizations and premature death. In 2010, ARB estimated that the number of annual PM2.5-related premature deaths is approximately 9,000 in California.[15] Thus, black carbon mitigation measures and the associated decline in PM provide both immediate climate benefits and important health and economic co-benefits. ARB has taken significant action in the past two decades to reduce PM and black carbon emissions, but more must be done to meet the State's climate and air quality goals.

II. Estimated emission benefits of the 1 mg/mi standard

The projected emission benefit from the 1 mg/mi standard was updated using EMFAC 2014 to calculate the PM2.5 benefits. Table 1 below summarizes the phase-in of the LEV III 1 mg/mi FTP PM standards which begins phasing in with 25% of vehicles in MY 2025, and full compliance by MY 2028.

Table 1 - Adopted phase-in of 1 mg/mi PM standard

	2025 MY	2026 MY	2027 MY	2028 MY
Percent of vehicles meeting the 1 mg/mi standard	**25%**	**50%**	**75%**	**100%**

For the analysis, FTP composite emission rates for future GDI vehicles were estimated to be 1.5 mg/mi and 0.7 mg/mi for vehicles certified to the 3 mg/mi and 1 mg/mi certification standards, respectively. The emission rate of 1.5 mg/mi for vehicles complying with the 3 mg/mi standard was based on the current test results shown in Appendix K, older ARB test results of low PM emitting vehicles, manufacturer information about expected compliance levels, and experience with historical criteria pollutant compliance. Similarly, the emission rate of 0.7 mg/mi for vehicles complying with the 1 mg/mi standard was based on a subset of the test results shown in Appendix K combined with analyzing the distribution of PM emissions during the test cycle to estimate a likely distribution that would lead to a composite test result, with some headroom, for compliance with the 1 mg/mi standard.

II.A Results of the analysis

The results of the analysis are provided in statewide tons per year of PM2.5 benefits. Results are also provided for the San Joaquin Valley basin given the particular focus on further PM reductions needed in that region. For reference, mobile sources are projected to emit 25,000 tons per year statewide and 3,000 tons per year in the San Joaquin Valley Air Basin in 2035.[16] Figure 1 below shows the statewide benefits estimated from the standard approach 200 tons/year, or 0.55 tons/day, by 2050.

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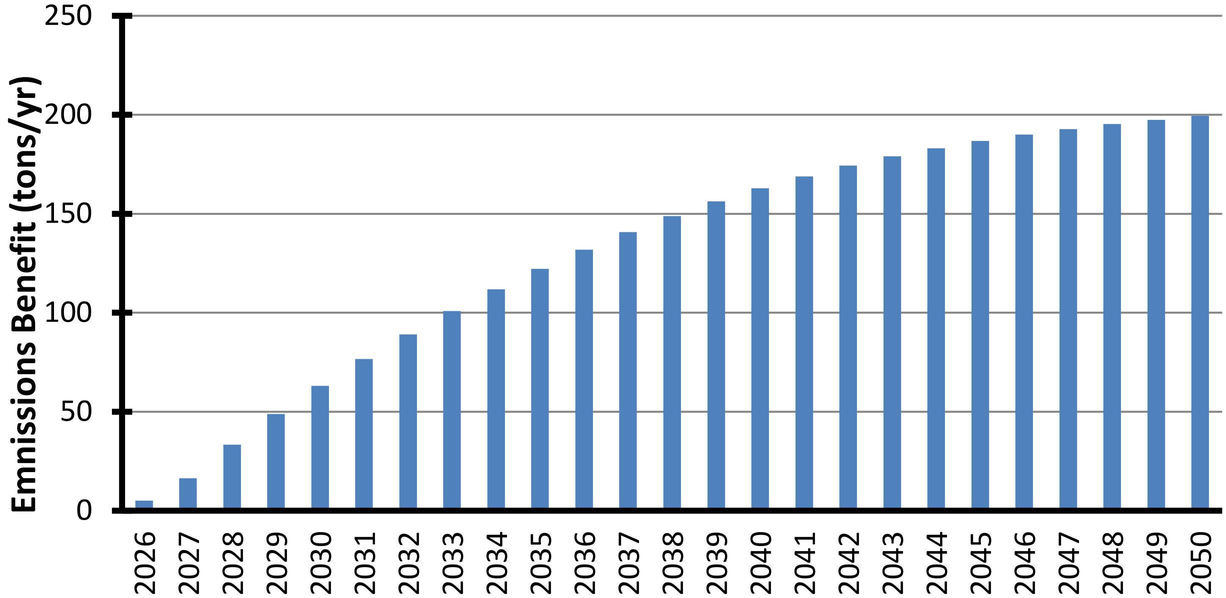
[15] ARB, 2010. California Air Resources Board. "Estimate of premature deaths associated with Fine Particle Pollution (PM2.5) in California using a U.S. Environmental Protection Agency methodology." August 2010. https://www.arb.ca.gov/research/health/pm-mort/pm-report_2010.pdf

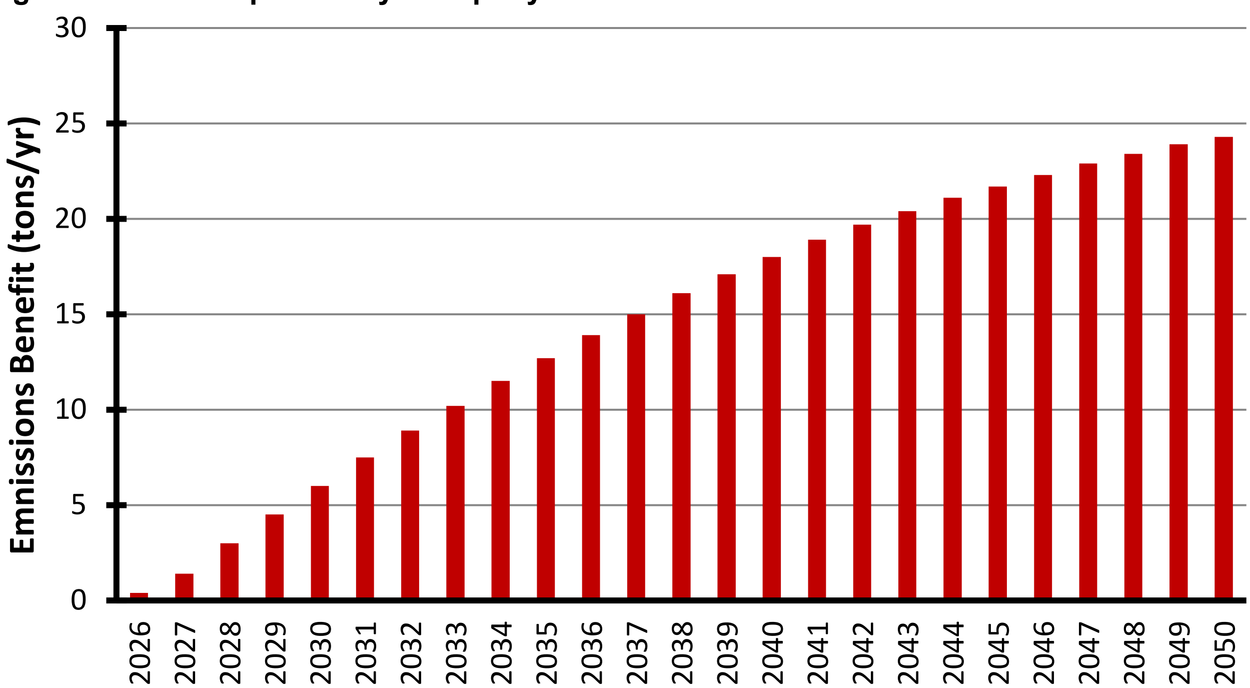
[16] ARB, 2013. California Air Resources Board. "Almanac Emission Projection Data." 2013. https://www.arb.ca.gov/app/emsinv/2013/emssumcat.php

Figure 1 - Statewide tons per year of PM2.5 benefits



For the San Joaquin Valley, the estimated benefits are shown in Figure 2 below. Relative to the statewide benefits, the benefits are smaller but not insignificant, approaching 25 tons/year, or 0.07 tons/day, in 2050.

Figure 2 - San Joaquin Valley tons per year of PM2.5 benefits



II.A.1 Earlier implementation of the standard

The Board directed staff in the Resolution, “that in the interest of the Board’s goal of reaching the proposed 1 mg/mi PM standard before the 2025 timeframe”, staff should assess the feasibility of implementing the standard earlier than adopted. Appendix J provides staff’s assessment of the status of PM control technology including the readiness of technology for an earlier implementation. However, to provide perspective on the impact of earlier implementation, staff analyzed the incremental emission benefit of earlier implementation of the 1 mg/mi PM standard.

II.A.2 Assumptions for early implementation analysis

Staff analyzed the incremental emission benefit of phasing in the 1 mg/mi PM standard immediately following the last year of the 3 mg/mi phase-in. The evaluated phase-in is shown in Table 2 below and, respective to regulatory process and lead time requirements, represents the earliest possible phase-in of the 1 mg/mi standard. The scenario effectively reflects an implementation of the 1 mg/mi standard three years earlier than scheduled.

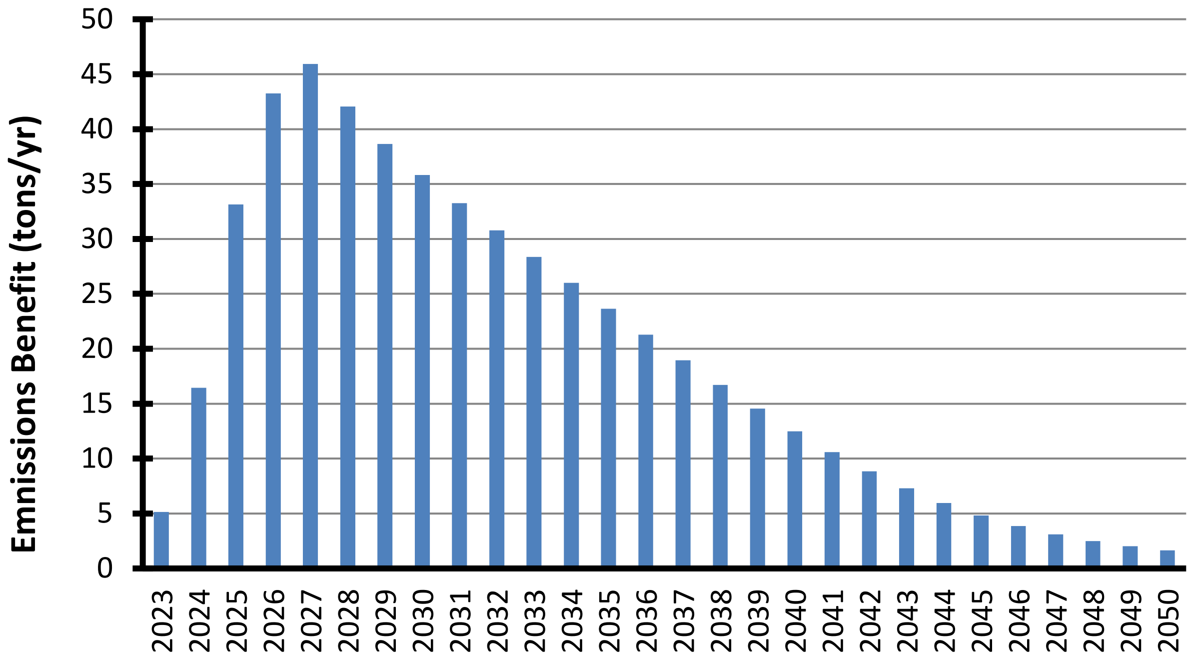
Table 2 - Early phase-in of 1 mg/mi PM standard scenario

	2022 MY	2023 MY	2024 MY	2025 MY
Percent of vehicles meeting the 1 mg/mi standard	25%	50%	75%	100%

II.B Results of emission benefit analysis

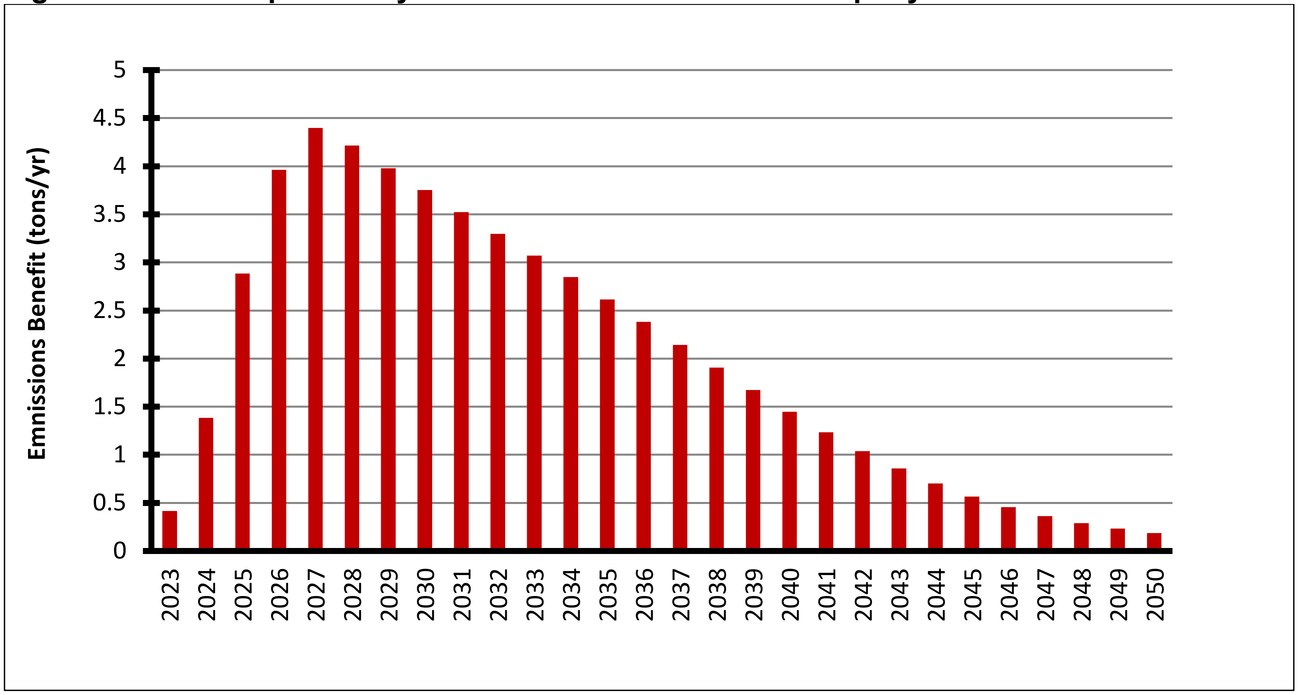
The results of the analysis are provided in tons per year of PM2.5 benefits for both statewide and for the San Joaquin Valley basin. Staff used EMFAC 2014 to estimate the environmental benefits of earlier implementation. The statewide emissions results are shown in Figure 3 and while they show the maximum incremental emission benefits approach 50 tons/year, or 0.13 tons/day in 2027, the benefits decrease subsequent to that. By 2040, the earlier implementation results in just over 12 tons/year, or 0.03 tons/day, of annual and benefit and no additional annual benefit by 2050. For perspective, total statewide exhaust PM emissions from light-duty vehicles are estimated to be 2.2 tons/day in 2040 so the earlier implementation would reflect an approximate 1% increase in benefits.

Figure 3 - Statewide PM Emissions benefits in tons per year



Looking at the San Joaquin Valley Air Basin, the emission benefits from earlier implementation are shown in Figure 4. Maximum emission reductions are less than 5 tons/year, or 0.01 tons/day. By 2040, benefits are less than 1.5 tons/year, or 0.004 tons/day. By 2025, the tentative deadline for compliance requested in the recently proposed San Joaquin Valley SIP, the early implementation would provide less than 0.01 tons/day of benefit which represents less than a 1% reduction in on-road mobile source estimated PM emissions in the SJV or less than 0.01% relative to all PM sources in the SJV.

Figure 4 - San Joaquin Valley PM Emissions benefits in tons per year



II.C PM Inventory for Black Carbon

Over the past several decades, California's actions to improve air quality, fight climate change, and protect public health have resulted in significant short-lived climate pollutant reductions including black carbon. California has cut anthropogenic black carbon emissions by over 90 percent since the 1960s, and existing measures are projected to cut mobile source emissions by 75 percent and total anthropogenic emissions by nearly 60 percent between 2000 and 2020. These reductions have come from strong efforts to reduce on-road vehicle emissions, especially diesel particulate matter. Car and truck engines used to be the largest sources of black carbon emissions in California, but California's existing air quality policies will virtually eliminate black carbon emissions from on-road diesel engines within 10 years.

Black carbon emission reduction programs from the transportation sector in California include:

- ***Cleaner trucks and buses:*** Current regulations will reduce black carbon emissions from existing trucks and buses by 80% in 2020, compared to 2000 levels.
- ***Off-road and construction equipment:*** New engine standards for off-road vehicles will reduce their black carbon emissions by 60% in 2020, compared to 2000 levels.
- ***Clean fuel rules:*** Clean Fuel Specifications enable cleaner vehicle technologies for both cars and trucks. The Low Carbon Fuel Standard provides a strong financial incentive to develop clean fuel alternatives that lead to little or no emissions of black carbon.
- ***Cleaner freight technologies:*** The Air Resources Board has developed a Sustainable Freight Strategy that will move California to a near-zero emission freight transport by 2050.
- ***Funding for cleaner cars and trucks:*** Approximately $1.6 billion has been distributed over the past 15 years to clean up diesel engines and reduce black carbon emissions

California's black carbon emissions inventory relies on PM inventories coupled with speciation profiles that define the fraction of PM that is black carbon. The sources that emit black carbon are well understood from a control prospective and major anthropogenic (e.g., non-forestry) sources are regulated in California. The major anthropogenic sources of black carbon in 2013 include diesel-fueled mobile sources, fuel combustion and industrial processes, and residential fireplaces and woodstoves. Off-road mobile emissions account for over a third of statewide anthropogenic black carbon emissions. On-road mobile sources account for nearly a quarter of emissions, primarily from on-road diesel combustion. On-road gasoline and brake and tire wear emissions are smaller.

As pointed out earlier, cutting emissions of short-lived climate pollutants such as black carbon provides a significant pathway for slowing the impacts of climate change. ARB's proposed short lived climate pollutant reduction strategy[17] (reducing black carbon emissions by 50 percent and other SLCPs by 40 percent below current levels by 2030) rightly points out California's impressive track record in reducing black carbon emissions from mobile sources over the past fifty years through implementation of stringent particle mass emission standards for new vehicles and engines. The adopted 3 mg/mi and 1 mg/mi standards continue this work to reduce PM and black carbon emissions from the light-duty sector. California is committed to continuing to reduce emissions of black carbon to meet ongoing air quality and climate targets.

II.C.1 Assumptions for Black Carbon benefit calculations

Estimated black carbon emission reductions were calculated for the incremental emission benefit of the 1 mg/mi standard based on the BC to total PM regression as described in Appendix K. From recent testing, approximately 75% of gravimetric PM is made up of black carbon and this fraction was assumed for all of the estimated PM benefits calculated above for the 1 mg/mi standard.

Since BC concentrations vary spatially, it is difficult to quantify its global warming potential (GWP), and there are significant variations in the GWP values for BC emissions assigned to different regions. Regional differences in atmospheric BC concentrations, and hence the warming effects of BC, depend upon the regional climate, radiation properties, and deposition pathways.[18] Conclude that the GWP value varies by about ±30 percent between emitting regions.

Bond et al. recommend a global mean BC GWP of 900 for the 100-year time horizon commonly used in calculating CO2 equivalent benefits.[19] This should be considered a conservative estimate for fossil fuel BC forcing in California, as a 20-year time horizon (GWP of 3,200) gives a better perspective on the speed at which BC controls will impact the atmosphere relative to CO2 emission controls.

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[17] ARB, 2016. California Air Resources Board. "Proposed Short-lived Climate Pollutant Reduction Strategy" April 2016. https://www.arb.ca.gov/cc/shortlived/meetings/04112016/proposedstrategy.pdf.
[18] Bond, 2013.
[19] Bond, 2013.

II.C.2 Black Carbon – summary of benefits

Black carbon emissions reductions are calculated based on the BC to total PM regression as described in Appendix K. Overall 75% of gravimetric PM is made up of black carbon. Using the assumptions and methodology noted above, Based on the inventory analysis the black carbon benefits were calculated in units of CO2 equivalent million metric tons (MMTCO2e) for direct comparison to other 100-year GWP calculations of GHG benefits. The statewide black carbon benefits in 2050 are estimated to be resulting MMTCO2e for the 1 mg/mi standard in 2050 is 0.12 MMTCO2e. When compared to the 2050 target of 85 MMTCO2e for all sources in California, and with 15 MMTCO2e of that 85 attributed to for all light duty vehicles, in 2050 the climate change benefit from the light duty 1 mg/mi PM standards is small but directionally helpful. When utilizing the 20-year GWP values (3200) instead of the 100-year values, the benefits are calculated to be 0.43 MMTCO2e in 2050. Further, the increased localized sensitivity to black carbon in California as noted earlier and the immediate benefits from further reductions support continued aggressive actions to reduce all sources where feasible and are consistent with ARB's proposed short lived climate pollutant reduction strategy.

III. Summary of health effects and emission benefit calculations

The relationship between PM exposure and health effects is well documented in that increased exposure leads to cardiopulmonary disease. The black carbon fraction of PM also has a strong GWP, between 900 and 3200 times more powerful than CO2, making even small reductions in black carbon directionally beneficial to meeting California's GHG reduction goals. The PM and black carbon benefits from the 1 mg/mi standard are small but appreciable however the incremental benefits associated with earlier implementation are so small as to be below the margin of error of the health effects analysis method.

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